SKID STEER VEHICLE WITH BELT DRIVE SUSPENSION

Field of the Invention

[0001] The invention relates generally to skid steer vehicles and, more particularly, it relates to belt driven suspensions for such vehicles.

Background of the Invention

[0002] Skid steer loaders were first invented about 30 years ago to fill a need for a small, highly maneuverable vehicle that was capable of carrying an implement mounted on loader arms. Skid steer loaders are typically small vehicles, on the order of 10 to 14 feet long that rest on four or more wheels, at least two of which being disposed on each side of the vehicle.

[0003] In order to turn these vehicles, the wheels on opposing sides of the skid steer loader are driven at different speeds. This causes the faster moving wheels on one side to advance that side over the ground faster than the other side on slower moving wheels. The effect is to turn the vehicle toward the wheels on the slower moving side. Since the wheels are not turnable with respect to the vehicle, the vehicle turns by skidding slightly, hence the name "skid steer loader."

[0004] In the extreme case the wheels on one side of the vehicle not only rotate slower than the wheels on the other side of the vehicle but can turn in the opposite direction. When this mode of operation is selected, the skid steer loader will rotate in place about a vertical and generally stationary rotational axis. This mode of operation requires the greatest amount of wheel skidding and as a consequence creates ruts and wears tires.

[0005] This ability to change direction by rotating about an axis within the footprint or perimeter of the loader itself was the primary reason why the skid steer loader achieved its great success.

[0006] Steering by skidding does place an extreme strain on the suspension components of the vehicle. For this reason traditional skid steer vehicles have no sprung suspensions. Instead, they have axles mounted directly to the sidewalls of the skid steer vehicle. Their axles are usually fixed with respect to the vehicle's sidewalls and the wheels are bolted on the ends.

[0007] In the traditional skid steer vehicle, the wheels on each side of the vehicle are driven by a link belt (e.g. a chain). The belts are contained in one or two chain tanks that are located inside the body of the vehicle. These tanks are typically formed from structural members of the vehicle such as the steel sidewalls of the chassis. These structural members are sealed to create fluid tight tanks that are filled with lubricant. When the belts are driven by hydraulic motors, they run through the lubricant in the tanks.

[0008] New skid steer vehicles having sprung suspensions have been devised in recent years, several of them by the inventors of this patent application. These suspensions typically employ gears and shafts.

[0009] This use of a gear and shaft arrangement requires significant additional manufacturing cost, due to the need to make custom gears, accurately machine shafts, and accurately locate the shafts with respect to one another.

[0010] The use of gears and shafts also increases the unsprung weight of the vehicle and the overall dimensions of the housings in which the gears are mounted.

[0011] What is needed, therefore, is a skid steer vehicle having a reduced unsprung weight. What is also needed is a skid steer vehicle having belts coupling the vehicle's drive motors with the driven wheels. What is also needed are vehicle belt drive housings that are

configured to internally support drive belts. What is also needed is a belt drive arrangement that accommodates a sprung suspension.

Summary of the Invention

[0012] In accordance with a first aspect of the invention, a skid steer vehicle is provided that has a chassis, an engine mounted on the chassis, left front and right front wheels independently pivotally mounted to the chassis, left rear and right rear wheels independently and pivotally mounted to the chassis, at least two left side drive belts operable coupled to a left side drive motor and to the left front and left rear wheels, at least two right side drive belts operably coupled to a right side drive motor and to the right front and right rear wheels, wherein the left side and right side motors are drivable to skid steer the vehicle.

[0013] The belts may be located outside the vehicle chassis. The motors may be mounted inside the chassis. Each motor may drive two sprockets, each of the two sprockets driving another belt, one coupled to the rear wheel and one coupled to the front wheel. The front and rear drive belts may extend the length of a fore and aft extending belt drive housing. The motor may be disposed between the front and rear wheels and have a motor shaft that extends through a sidewall of the vehicle coaxial with the pivot point of a belt drive housing. The motor may be coupled to and drive two adjacent shafts inside the vehicle chassis, and each shaft may extend through the sidewall of the vehicle coaxial with a pivotal axis of the front and rear belt drive housings. The belts may be link belts made of a plurality of links mechanically coupled together, or they may be flexible composite belts having an internal core of load-carrying fibers surrounded by a flexible elastomeric matrix. Each belt may be coupled at one end to a drive shaft extending from the sidewall of the vehicle and at another end to a sprocket coaxial with the rotating wheels it drives.

Brief Description of the Drawings

[0014] The drawings illustrate the best mode presently contemplated for carrying out the invention.

[0015] **FIGURE 1** is a side view of a skid steer vehicle in accordance with the present invention.

[0016] **FIGURE 2** is a top view of the left side of the skid steer vehicle in partial cross section taken generally along line 2-2 in **FIGURE 1** and showing the arrangement of the belt drive components.

[0017] **FIGURE 3** is a partial fragmentary detail view of the center left side vehicle showing details of the belt drive housings where they are coupled to the chassis. The right side of the vehicle is a mirror of the left side, mirrored about the longitudinal axis of the vehicle.

[0018] **FIGURE 4** is a schematic diagram of the hydraulic drive circuit that moves the vehicle over the ground.

Detailed Description of the Invention

[0019] Referring now to **FIGURES 1-3**, the loader includes a chassis or frame **100** to which four wheels **102** are connected, two wheels on each side. An engine **104** is coupled to and drives three hydraulic pumps **106**, **108** and **110**. Pumps **106** and **108** provide hydraulic fluid to the hydraulic drive motors (**FIG. 4**) to turn the wheels **102**. Hydraulic pump **110** is driven by engine **104** as a charge pump to provide makeup hydraulic fluid to the vehicle's drive motors (**FIG 4**). Pumps **106** and **108** are variable displacement bi-directional flow hydraulic pumps.

[0020] The lift cylinders **112** are pivotally coupled to and between the chassis and the loader arms **120** to lift the loader arms with respect to the vehicle. Bucket cylinders **114** are coupled to and between the loader arms **120** and a bucket **116** to tilt the bucket with respect to the loader arms. Bucket **116** is pivotally coupled to loader arms **120** at pivot joint **118**. It pivots about a substantially horizontal axis with respect to the loader arms when cylinder **114** is retracted or extended. In a similar fashion, loader arms **120** are pivotally coupled to chassis **100** at pivot joints **122** such that the loader arms raise and lower whenever the cylinders **112** extend and retract, respectively. Pivot joints **122** and **126** are located behind the operator seat **141**. The lift cylinders **112** are pivotally coupled both to the loader arms and to the chassis at pivot joints **124** and **126**, respectively. A heavy duty cage **128** called a ROPS extends about the operator's compartment **130**.

[0021] Each of the four wheels **102** is rotatably connected to a first end of an associated belt drive housing **132**. The opposing end of each belt drive housing is pivotally coupled to the vehicle chassis **100** at a pivot joint **134** which permits the first end to move up and down with respect to the chassis, and permits the housing **132** to pivot with respect to the chassis.

[0022] Each belt drive housing **132** is spring mounted and damped by one or more hydraulic cylinders **138** that are coupled at their lower ends to the belt drive housing and at their upper ends to chassis **100**. Whenever belt drive housings **132** pivot with respect to chassis **100** at their pivot joints **134**, hydraulic cylinders **138** damp the motion of the belt drive housings. These hydraulic cylinders are fluid-filled with hydraulic fluid, gas or a combination of the two. Cylinders **138** may be self-contained or may have external connections to a separate supply of hydraulic fluid and/or gas. The hydraulic cylinders **138** are used as springs to support their associated wheels.

[0023] In a preferred embodiment, each hydraulic cylinder **138** includes an internal or external gas-charged accumulator that forces the hydraulic cylinder **138** into an extended position. In this position, the gas charge acts as a spring to support the vehicle on the belt drive housings. This arrangement may supply the total springing for the vehicle, or it may be supplemented (or replaced by) springs disposed elsewhere on the vehicle.

[0024] Engine **104** is preferably a two- to six-cylinder internal combustion engine, preferably a diesel engine, and is preferably disposed such that its crankshaft extends parallel to the longitudinal extent of chassis **100**.

[0025] Pumps **106**, **108**, and **110** preferably are coupled together in series and to engine **104**. In this preferred arrangement, the pump shafts are rotationally coupled to the crankshaft of engine **104**.

[0026] Two of the belt drive housings **132** are coupled to the vehicle and extend forward to the two front wheels **102**. They each have a front end **140** and a rear end **142**. They pivot with respect to the chassis about horizontal and lateral pivot axis **144**. These two housings **132** extend forward and substantially horizontally, terminating at front wheels **102** to which they are coupled and which they support.

[0027] Two of the belt drive housings **132** are coupled to the vehicle and extend backward to the two rear wheels **102**. They each have a front end **146** and a rear end **148**. They pivot with respect to the chassis about horizontal and lateral pivot axis **150**. These two housings **132** extend backward and substantially horizontally, terminating at rear wheels **102** to which they are coupled and which they support.

[0028] Each side of the vehicle is equipped with two belt drive housings **132** that support shafts driven by a hydraulic motor. Hydraulic motor **152** is coupled to and drives a

first drive shaft **154** coaxial with motor **152**. Hydraulic motor **152** also drives a second drive shaft **156** that is parallel to and adjacent to shaft **154**.

[0029] A belt **158** couples sprockets **160** and **162** that are located on shafts **154**, **156**, respectively. The belt transfers power from motor **152** to shaft **156** thereby permitting motor **152** to drive both shafts **154** and **156** simultaneously.

[0030] Shafts **154** and **156** extend through sidewall **164** of the vehicle and extend into forward belt drive housings **132** and rearward belt drive housing **132**, respectively. Shafts **154** and **156**, in turn, are coupled to and drive front and rear wheels **102**, respectively. Motor **152** thereby drives both the front and rear wheels on the left side of the vehicle.

[0031] Referring now to the forward belt drive housing, sprocket **161** is mounted on drive shaft **154**. A belt **166** is wrapped around and engaged to sprocket **161**. Belt **166** extends forward to and wraps sprocket **168** which it drives in rotation. Sprocket **168** in turn is mounted on and drives shaft **170** in rotation. Drive shaft **170** extends through outer wall **172** of the front belt drive housing **132** and is fixed to a flange **174** which it drives in rotation. Front wheel **102** is mounted on and driven by flange **174**.

[0032] Referring now to the rear belt drive housing, sprocket **163** is mounted on drive shaft **156**. A belt **176** is wrapped around and engages with sprocket **163**. Belt **176** extends backward to and wraps sprocket **178** which it drives in rotation. Sprocket **178** in turn is mounted on and drives shaft **180** in rotation. Drive shaft **180** extends through outer wall **182** of the rear belt drive housing **132** and is fixed to a flange **184** which it drives in rotation. Rear wheel **102** is mounted on and driven by flange **184**.

[0033] The forward belt drive housing is made of an outer wall **172** and an inner wall **186** that are fixed together to define an enclosure that is configured to contain its drive belt.

The rear belt drive housing is made of an outer wall **182** and an inner wall **187** that are fixed together to define an enclosure that is configured to contain its drive belt. Each belt drive housing **132** is pivotally coupled to the chassis **100** of the vehicle by two spaced-apart spherical bearings **188**, **190**. These bearings constrain the movement of the belt drive housing they are attached to such that housing **132** pivots with respect to the vehicle. The front belt drive housing pivots about axis **144** that is coaxial with belt drive sprockets **160** and **161** and the rear belt drive housing pivots about axis **150** that is coaxial with sprocket **162** and **163**. The belt drive housings are configured to keep the length of their respective belts constant as the housings pivot, maintaining a preferred belt tension.

[0034] **FIGURES 2** and **3** illustrate the belt drive housings of the left side of the vehicle. The right side of the vehicle is identical but in mirror form, mirrored about the longitudinal central axis **189** of the vehicle. Thus the vehicle has two motors, one on each side of the vehicle, each motor driving two belts, one belt disposed in each of a forwardly extending front belt drive housing and a backwardly extending rear belt drive housing. Because the construction of the right side of the vehicle is the same as the construction of the left side of the vehicle, it has been omitted from **FIGURE 2**.

[0035] The hydraulic drive system is shown in **FIGURE 4**, which illustrates hydraulic drive circuit **200**, the circuit that includes the pumps motors and interconnecting components for driving the wheels **102**.

[0036] Hydraulic circuit **200** is configured to operate the two hydraulic drive motors **152**, which are identified in **FIGURE 4** as left side drive motor **152**, and right side drive motor **152A**. The four wheels **102** are identified as left front wheel **102A**, right front wheel **102B**, left rear wheel **102C** and right rear wheel **102D**.

[0037] Hydraulic drive motor **152** is connected in series with pump **106** to provide a continuous hydraulic fluid flow circuit from pump **106** through motor **152** then back to pump **106** in a first fluid flow direction. The operator can vary the displacement of pump **106** to drive fluid in the opposite fluid flow direction, i.e. pumping fluid from pump **106** in the opposite direction through hydraulic drive motor **152**, then back to pump **106**. The flow direction and magnitude are controlled electronically by drive controller **202** which is coupled to and controls the displacement of both pumps **106**, **108** in response to operator manipulation of an operator input device, here shown as joystick **204**.

[0038] Pump **108** and hydraulic drive motor **152A** are identically configured to provide bi-directional fluid flow and are identically controlled by drive controller **202** in response to operator manipulation of joystick **204** to which controller **202** is coupled.

[0039] The vehicle therefore has two separately controllable hydraulic drive circuits. One circuit connects pump **106** and hydraulic drive motor **152** to drive wheels **102** on the left side of the vehicle. Another circuit connects pump **108** and hydraulic drive motor **152A** to drive wheels **102** on the right side of the vehicle.

[0040] Drive controller **202** is coupled to pumps **106** and **108** and is configured to separately and independently vary the speed and rotational direction of the hydraulic drive motors **152**, **152A** on opposing sides of the vehicle in response to operator commands that joystick **204** is configured to transmit to it. In the preferred embodiment it does this by varying the specific displacement of pumps **106**, **108**. This drive system is therefore operable to simultaneously drive hydraulic motors on opposing sides of the vehicle in opposite directions and also to simultaneously drive them in the same direction.

[0041] The two hydraulic drive circuits that make up drive circuit **200** include two additional circuit elements **206**, **208** that are connected in parallel with the pumps **106**, **108**,

respectively. These circuit elements **206**, **208** include overpressure relief valves and hydraulic fluid make-up circuits. Relief and makeup circuit **206** is coupled to the drive circuit for the wheels on the left hand side of the vehicle, including pump **106** and hydraulic drive motor **152.** Relief and makeup circuit **208** is coupled to the drive circuit for the wheels on the right hand side of the vehicle, including pump **108** and hydraulic drive motors **152A.**

[0042] Drive controller **202** is preferably a digital drive controller that includes one or more microprocessors or microcontrollers that are coupled together in a network, preferably a CAN bus network in accordance with SAE J1939 to control the devices in the manner described herein. Controller **202** generates signals that it applies to pumps **106** and **108** to control the displacement, flow rate and direction of fluid flow through the pumps.

[0043] Joystick **204** preferably provides signals indicative of the displacement of the joystick in two orthogonal directions. It may be a made with variable resistors, potentiometers, rotary shaft encoders, Hall effect devices or similar components.

[0044] While the embodiments illustrated in the FIGURES and described above are presently preferred, it should be understood that these embodiments are offered by way of example only. The invention is not intended to be limited to any particular embodiment, but is intended to extend to various modifications that nevertheless fall within the scope of the appended claims. The hydraulic system may be manually operated and not electronically operated. For example, in place of the electronic controller and joystick, one or more levers coupled to pumps **106** and **108** may be provided to control the displacement of the pumps.